Models of Cognition in Distributed Learning Environments

MOVES Annual Research & Education Summit
Naval Postgraduate School
Monterey, CA
13 July 2010

J. D. Fletcher
Institute for Defense Analyses

fletcher@ida.org

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **13 JUL 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Models of Cognition in Distributed Learning Environments**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Institute for Defense Analyses,4850 Mark Center Dr ,Alexandria,VA,22311**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
10th Annual MOVES Research and Education Summit 2010, 13-15 July.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**39**	

In Conclusion …

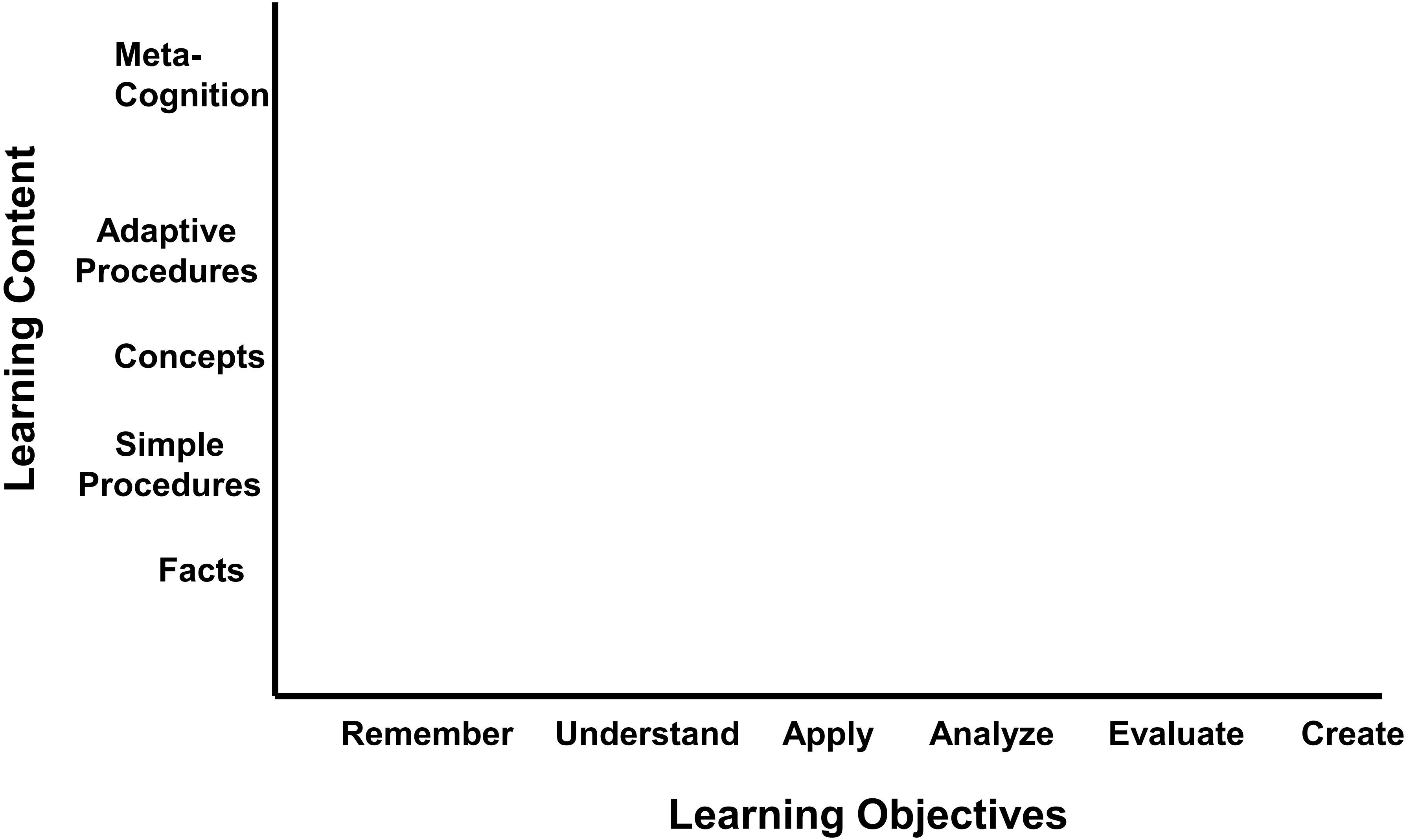
- Cognitive models are an instructional imperative … and no longer an economic impossibility.
- Cognitive models have been used in technology-based instruction from the beginning.
- Cognitive models are needed for simulation used to train. Open questions remain.

Two Cultures, Divided by a Common Language

Simulationists	Trainers
Collectives/Units	Individuals/Teams
Exercises	Programs of Instruction
Full Fidelity	Selective Fidelity
Big Simulation	Small Simulation

These are complementary not competing cultures.

How Trainers Think: Learning Objectives



(Framework courtesy of Anderson & Krathwohl, 2001)

On teaching: From Yue-zheng (4th C. BC) to Patrick Suppes to Jerome Bruner to …

"The principal consequence of … individual differences is that every general law of teaching has to be applied with consideration of the particular person, ... responses … to any stimulus … will vary with individual capacities, interests, and previous experience."

(E. L. Thorndike, 1906, *Principles of Teaching*)

Q&A: Why Bother with Cognitive Models?

Q: Why do we use cognitive models in instruction?
A: To tailor instruction to learners.

Q: Why do we want to tailor instruction to learners?
A: Because it is very efficient.

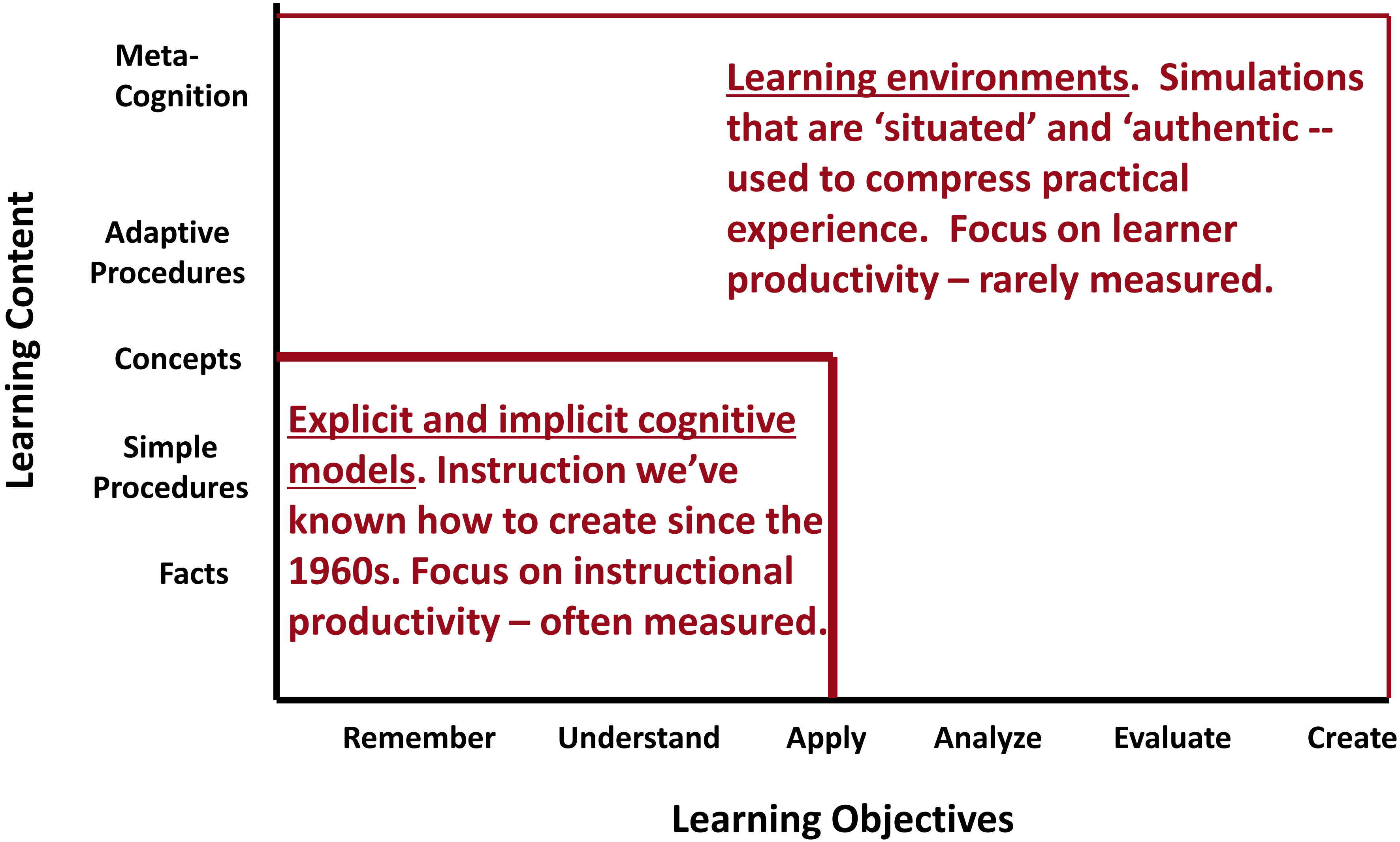
Q: Why do we want efficient training?
A: Because it contributes to productivity and effectiveness in operations – more can be done with fewer people and fewer resources.

On learning: From Aristotle (4th C. BCE) to William James to Norbert Weiner to …

“Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our mind.”

(William James, 1890 -- General Law of Perception in *Principles of Psychology*)

Cognitive Models in Education & Training

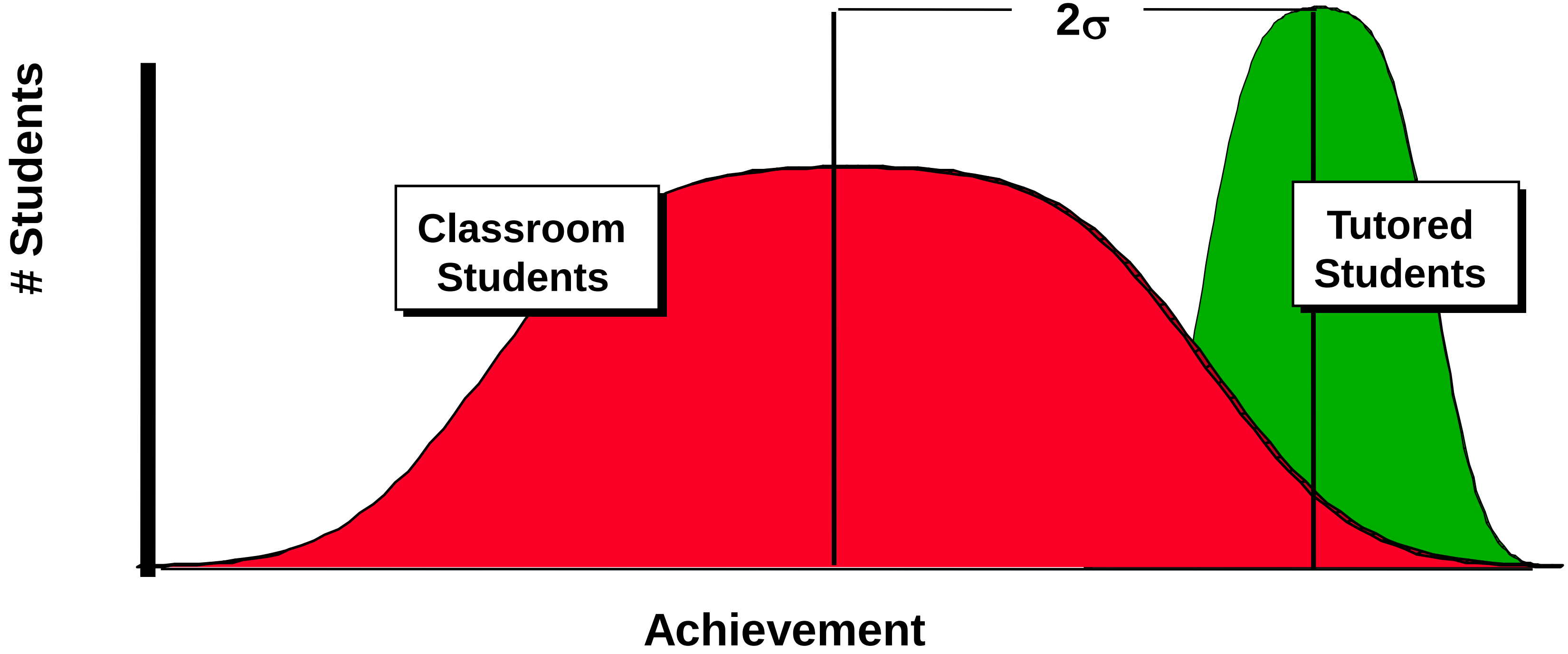


(Framework courtesy of Anderson & Krathwohl, 2001)

About Training

Cognitive models are an instructional imperative … and no longer an economic impossibility.

The Tutorial Imperative



Adapted From: Bloom, B.S. The Two Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring. Educational Researcher. 13, 4-16 (1984)

Why Is Tutoring So Effective?

- Individualization of
  - Sequence,
  - Content,
  - Style,
  - Difficulty,
  - and Pace.

- Intensified interactivity.

Enter the Computer: A Third Revolution in Learning?

- **Writing**

  Content of learning made available anytime, anywhere

- **Books**

  Affordable content of learning made available anytime, anywhere

- **Technology**

  Affordable content and interactions of learning made available anytime, anywhere

A DARPA Challenge

16 weeks of simulation-based, “intelligent” training to produce graduates who are superior to technicians with 7 years of IT experience in the Fleet.

Cognitive models have been used in technology-based instruction from the beginning.

An Intrinsic Cognitive Model: Keller’s PSI

Keller’s Personalized System of Instruction (PSI)

Modularized Instruction

Pre-Test → Diagnose & Assess → Study Guide → Post-test

Another Intrinsic Cognitive Model: Crowder's Intrinsic Programming

In the multiplication 3 X 4 = 12,
the number 12 is called a ______.

A. Factor [Branch to remedial X1]
B. Quotient [Branch to remedial X2]
C. Product [Reinforce, go to next]
D. Power [Branch to remedial X3]

PSI (Keller) with Intrinsic Programming (Crowder)

From previous module

Pre-test

Pass?

Yes, on to the next module

No, go to this module

In the multiplication 3 X 4 = 12,
the number 12 is called a _______.

A. Factor [Branch to remedial X1]
B. Quotient [Branch to remedial X2]
C. Product [Reinforce, go to next]
D. Power [Branch to remedial X3]

Post-test

Selecting an Item/Problem to Present Next: Some Models of Memory

		State on Trial n+1 When Presented				
		L	S	U		P(c)
State on Trial n	L	1	0	0		1
	S	c	1-c	0		1
	U	a	b	1-a-b		g

		State on Trial n+1 When Not Presented		
		L	S	U
State on Trial n	L	1	0	0
	S	c	1-c	0
	U	a	b	1-a-b

Allocating Time Among Students: Fun with Regression Equations

Linear:

$$E(O_i) = b_0 + b_1 P_i + b_2 T_i$$

Linear with interaction:

$$E(O_i) = b_0 + b_1 P_i + b_2 T_i + b_3 P_i T_i$$

Cobb-Douglas:

$$E(\ln O_i) = b_0 + b_1 \ln P_i + b_2 \ln T_i$$

Exponential:

$$E(\ln O_i) = b_0 + b_1 \ln P_i + b_2 \ln T_i + b_3 (\ln T_i)^2 + b_4 (\ln T_i)^3$$

(O = outcome; P = pretreatment measure; T = time)

Does it Work? The “Rule of Thirds” (A Statistical Summary)

Use of Technology-Based Instruction (adaptive and distributable) can reduce costs of instruction by about 1/3, and

Either increase learning by about 1/3 (Education)

Or reduce time to learn by about 1/3 (Training)

N.B.: The real payoff is increased effectiveness and productivity

Simulation in the Small: Simulation Meets Cognitive Modeling (and Vice Versa)

Tracking the Student ("Stealth Assessment")

Student: What is the base emitter voltage of t he voltage limiting transistor?

SOPHIE: The base emitter voltage of Q5 is -.037 volts.

Student: What about for the current limiting transistor?

SOPHIE: The base emitter voltage of Q8 is .349 volts.

Student: What should it be?

SOPHIE: In a working circuit, the base emitter voltage of Q8 is .593 volts.

Student: Replace Q8.

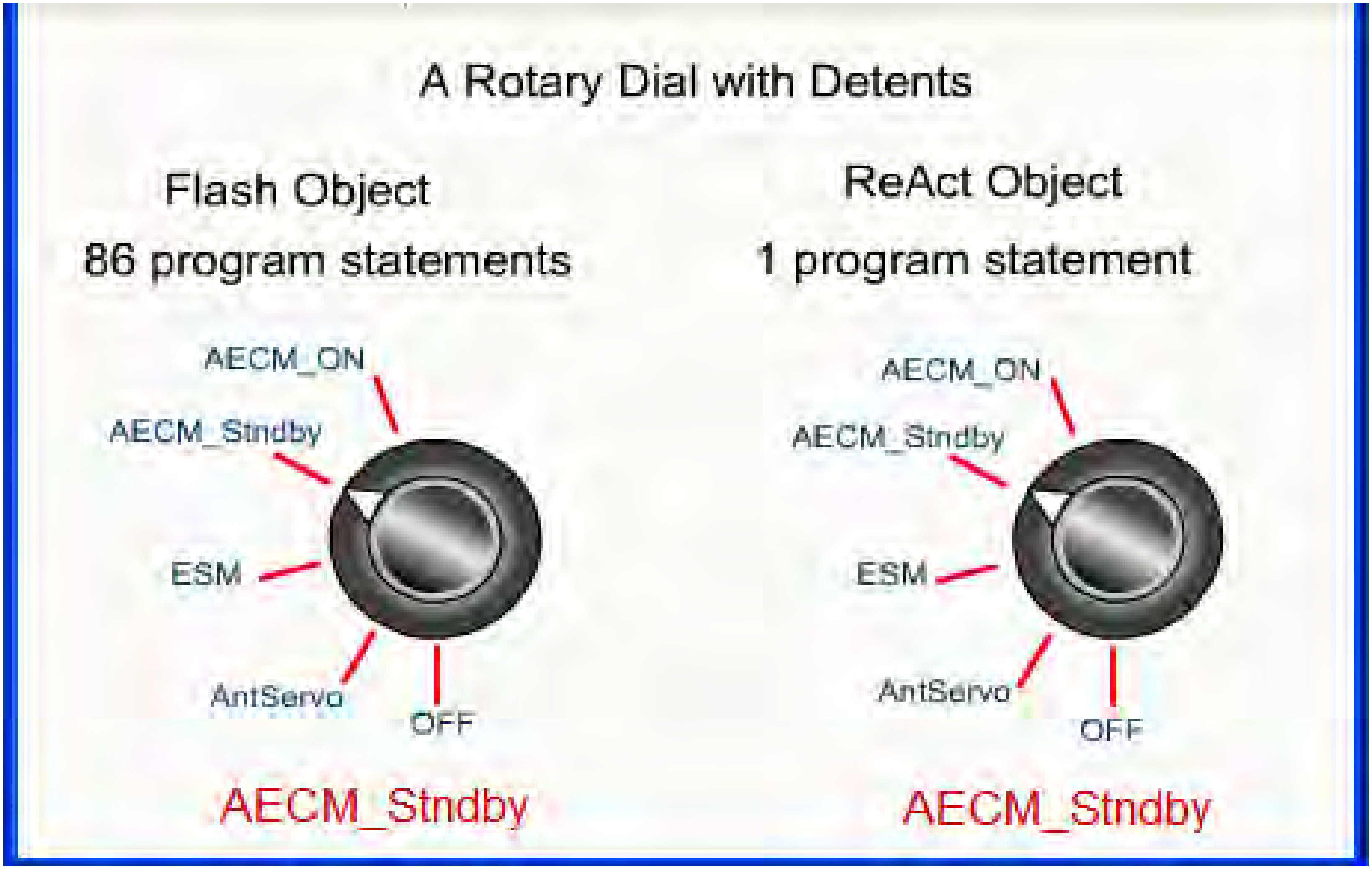
SOPHIE: I am going to ask you some questions about how Q8 is faulted. Are any junctions shorted?

(From Brown, Burton, & DeKleer, 1982)

Some Early ICAI/ITS Systems

SCHOLAR	South American geography	Carbonell, 1970
WHY	Causes of rainfall	Stevens, et al., 1982
INTEGRATE	Symbolic integration	Kimball, 1982
SOPHIE	Electronic troubleshooting	Brown, et al., 1982
WEST	Arithmetic expressions	Burton & Brown, 1979
BUGGY	Subtraction	Brown & Burton, 1978
WUSOR	Logical relations	Goldstein, 1982
EXCHECK	Logic and set theory	Suppes, 1982
BIP	BASIC programming	Barr, et al., 1976
SPADE	LOGO programming	Miller, 1982
ALGEBRA	Algebra word problems	Lantz, et al., 1983
LMS	Algebraic procedures	Sleeman, 1982
QUADRATIC	Quadratic equations	O'Shea, 1982
GUIDON	Infectious diseases	Clancey, 1982
MENO	PASCAL programming	Soloway, et al., 1983
STEAMER	Steam propulsion (USN)	Williams, et al., 1981

Simulation in the Small: DIAG Example



Simulation in the Large:
Preparing for Incredibly Complex Tasks

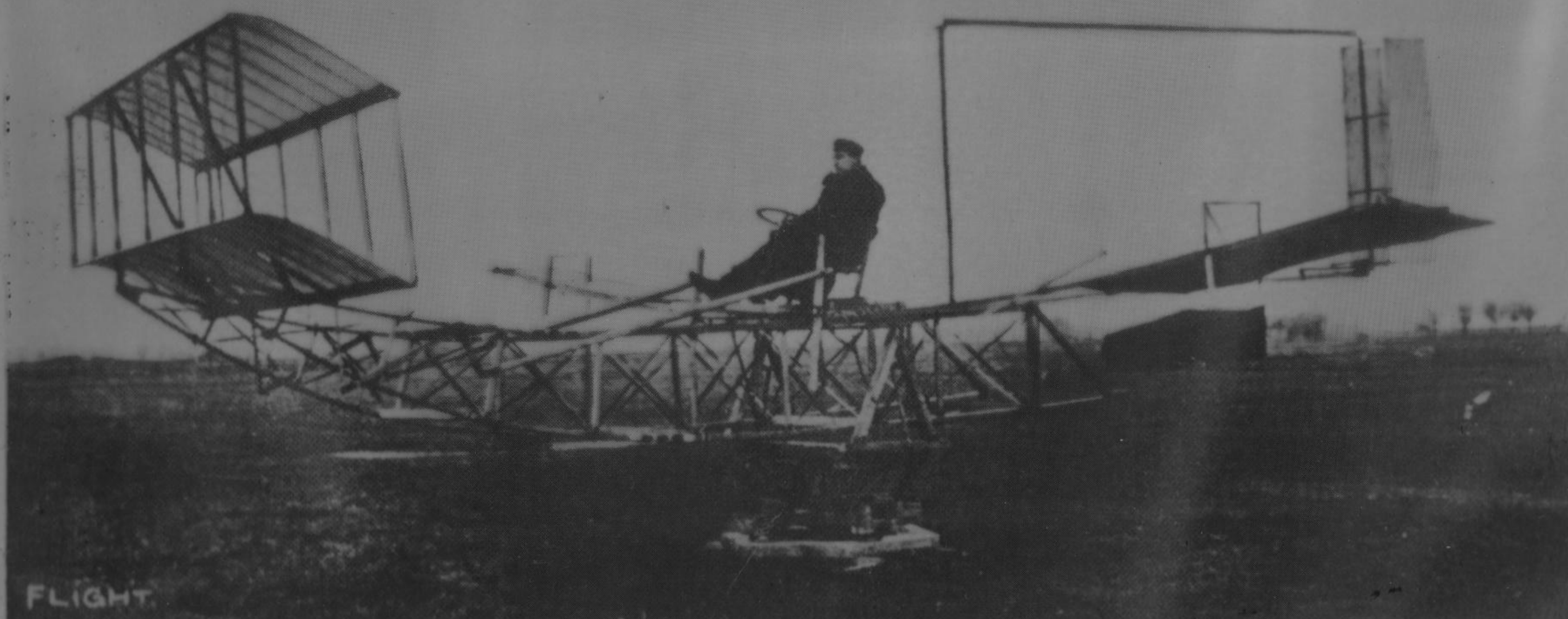
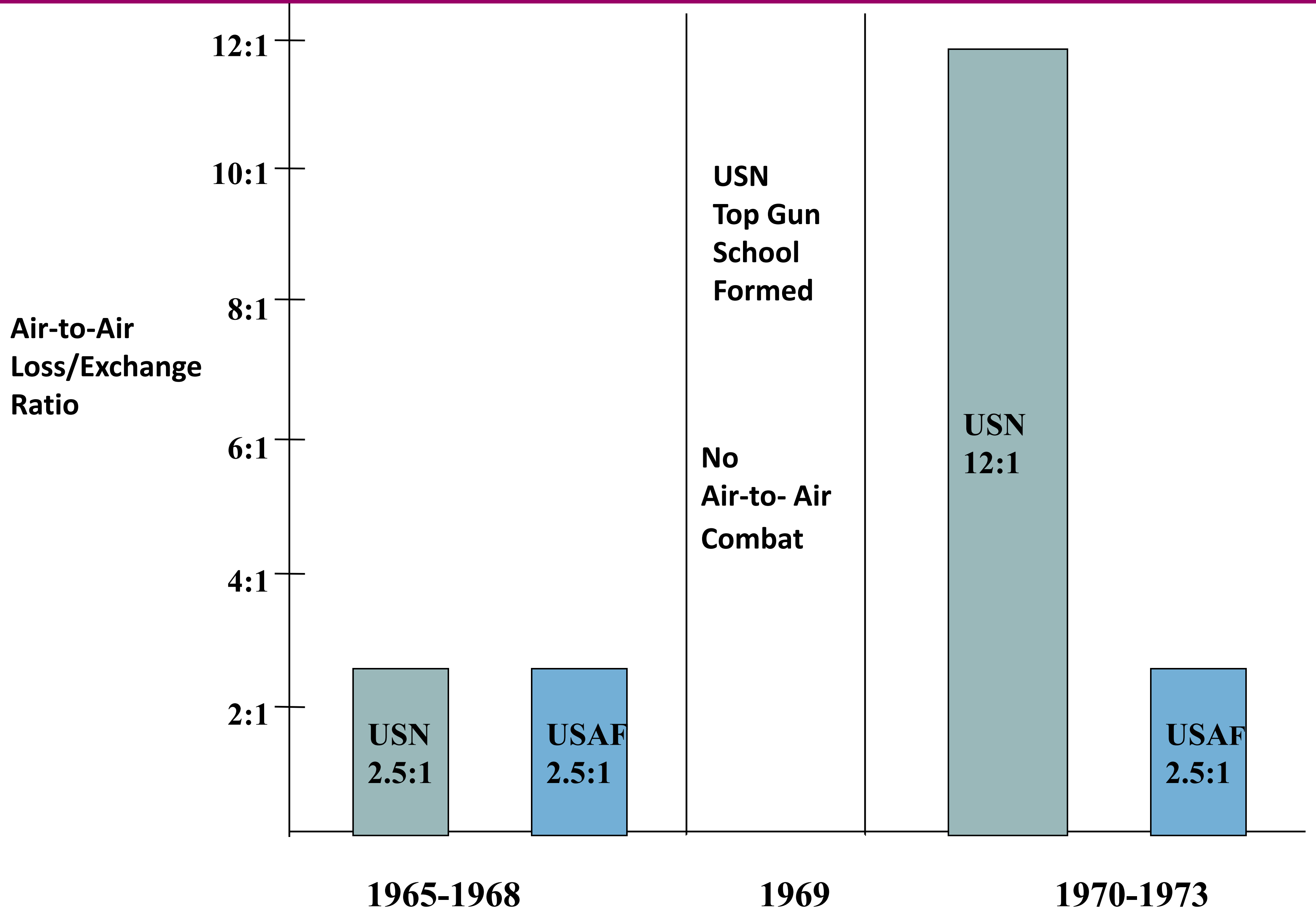


Figure 1. The Sanders teacher (flight trainer).

“Top Gun” Example



What Was Different?

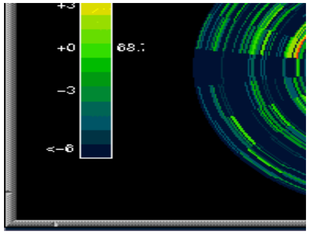
Before Top Gun	With Top Gun
No instrumentation	Instrumentation
Untrained OpFor	Trained OpFor
Umpires	Force on Force
Classroom Tactics	Practice in the Sky
Tests	"Situated" Assessment

From
REALTRAIN
to
MILES (Multiple Integrated Laser Engagement Simulation)
to
Simulation Networks
to
Irregular Warfare Training

Simulation for Irregular Warfare

What Value Do Cognitive Models Bring to Simulation in the Large?

Training for an Incredibly Complex Task: An IMAT Display



Incredibly Complex Tasks

Abstract	Physical phenomena or causation are not readily visible
Multivariate	Many variables underlie outcomes.
Interactive	Changes in one variable may affect several others. Processes are co-dependent.
Continuous	Physical phenomena and their effects are described as values along continua, rather than as discrete properties.
Non-Linear	Relations among variables are not simple straight-line functions
Dynamic	The process of variation is of interest, rather than end-state
Simultaneous	Systemic variation is coincident rather than serial.
Conditional	Outcomes are highly dependent on boundary conditions and context.
Uncertain	Exact values of underlying variables are not known precisely – they may be estimates, interpolations, approximations
Ambiguous	The same outcome may arise from different combinations of inputs.

Preparing for the Unexpected: Cognitive Readiness

Cognitive readiness **is the mental preparation (including skills, knowledge, abilities, motivations, and personal dispositions) an individual needs to establish and sustain competent performance in the complex and unpredictable environment of modern military operations.**

Some Open Questions

- **Do we need cognitive models in simulation in the large?**
- **What might be their value of cognitive models? (Design, development, implementation (AARs), assessment)**
- **From METLs to MECs – how do we prepare people for the unexpected – cognitive readiness?**
- **Cognitive models for teams?**
- **What are the psychometric characteristics of simulations (reliable, valid, precise)?**

Some Cognitive Models

- Atomic Components of Thought (ACT) & Atomic Components of Thought - Rational (ACT-R))
- Adaptive Resonance Theory (ART)
- Architecture for Procedure Execution (APEX)
- Business Redesign Agent-Based Holistic Modeling System (Brahms)
- Cognition and Affect Project (CogAff)
- Cognition as a Network Of Tasks (COGNET)
- Cognitive Complexity Theory (CCT)
- Cognitive Objects within a Graphical EnviroNmentT (COGENT)
- Concurrent Activation-Based Production System (CAPS)
- Construction-Integration Theory (C-I Theory)
- Distributed Cognition (DCOG)
- Executive Process/Interactive Control (EPIC)
- Human Operator Simulator (HOS)
- Man-machine Integrated Design and Analysis System (MIDAS)
- Micro Systems Analysis Of Integrated Network Of Tasks (Micro Saint)
- Operator Model Architecture (OMAR)
- PSI
- Situation Awareness Model for Pilot-in-the-Loop Evaluation (SAMPLE)
- State, Operator, And Result (SOAR)

In Conclusion …

- Cognitive models are an instructional imperative … and no longer an economic impossibility.
- Cognitive models have been used in technology-based instruction from the beginning.
- Cognitive models are needed for simulation used to train. Open questions remain.